THE FIRST HUMAN-ROBOTIC MISSION TO THE LUNAR FARSIDE USING THE ORION MPCV AT EARTH-MOON L2 AND A TELEOPERATED ROVER

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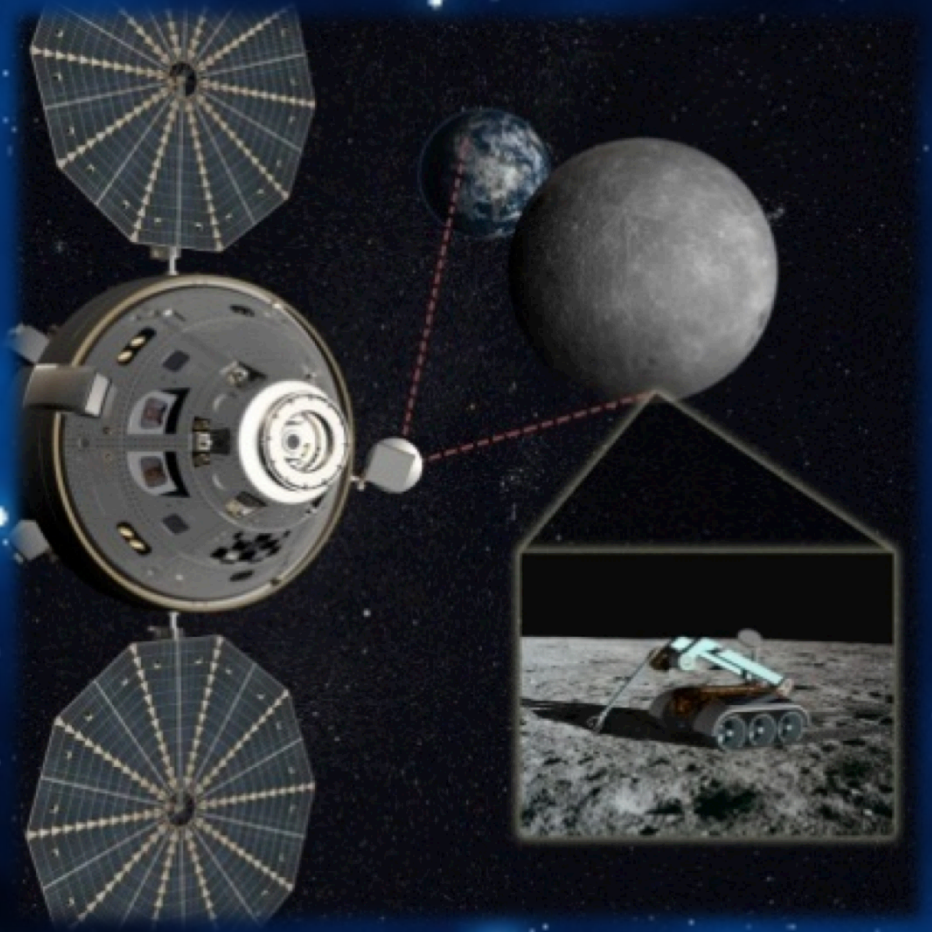

Lunar Science Forum

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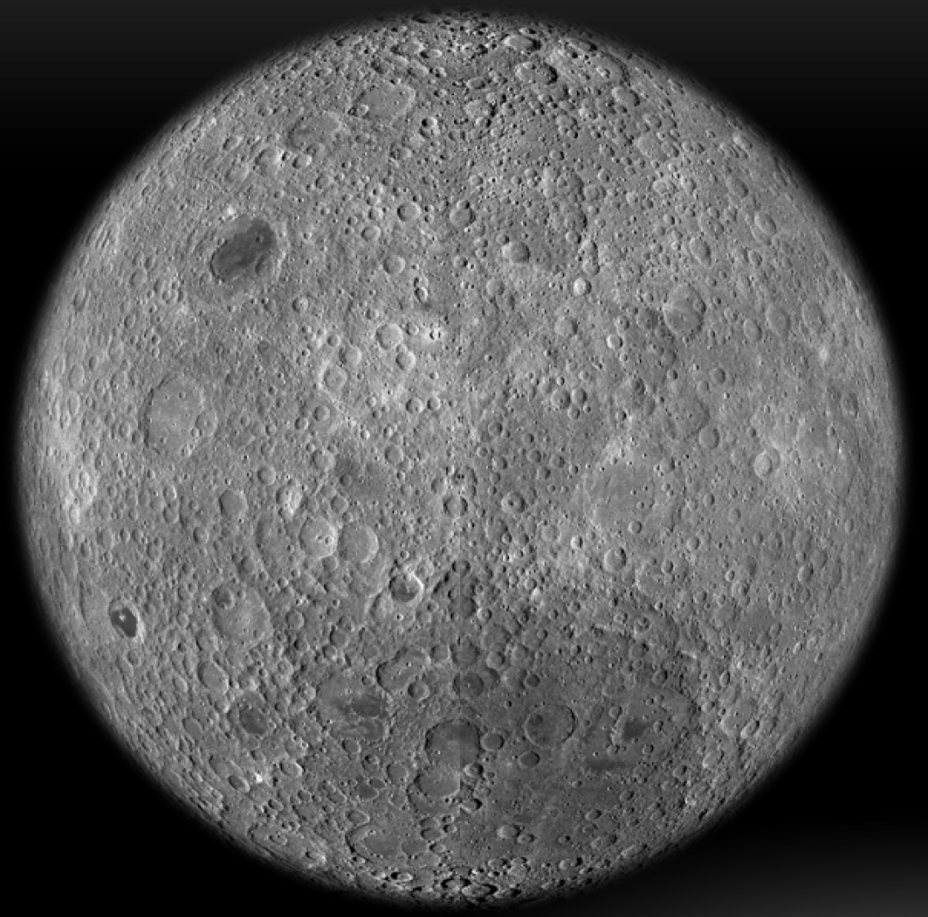
NASA Ames Research Center

THE LUNAR FARSIDE



- A whole new, *unexplored* world in Earth's backyard!
- Opportunity to demonstrate human-robotic exploration strategies needed to explore surfaces of the Moon, asteroids, & Mars.
- Lunar farside is dramatically different from regions investigated by Apollo – e.g., 1% maria on farside vs. 31% on nearside.
- Farside includes the South Pole-Aitken basin – possibly the largest, deepest, & oldest impact basin in the inner solar system.
- Because of Earth-Moon tidal locking, farside always faces away from Earth and is, therefore, the only pristine radio-quiet site to pursue observations of the early Universe's *Cosmic Dawn*.

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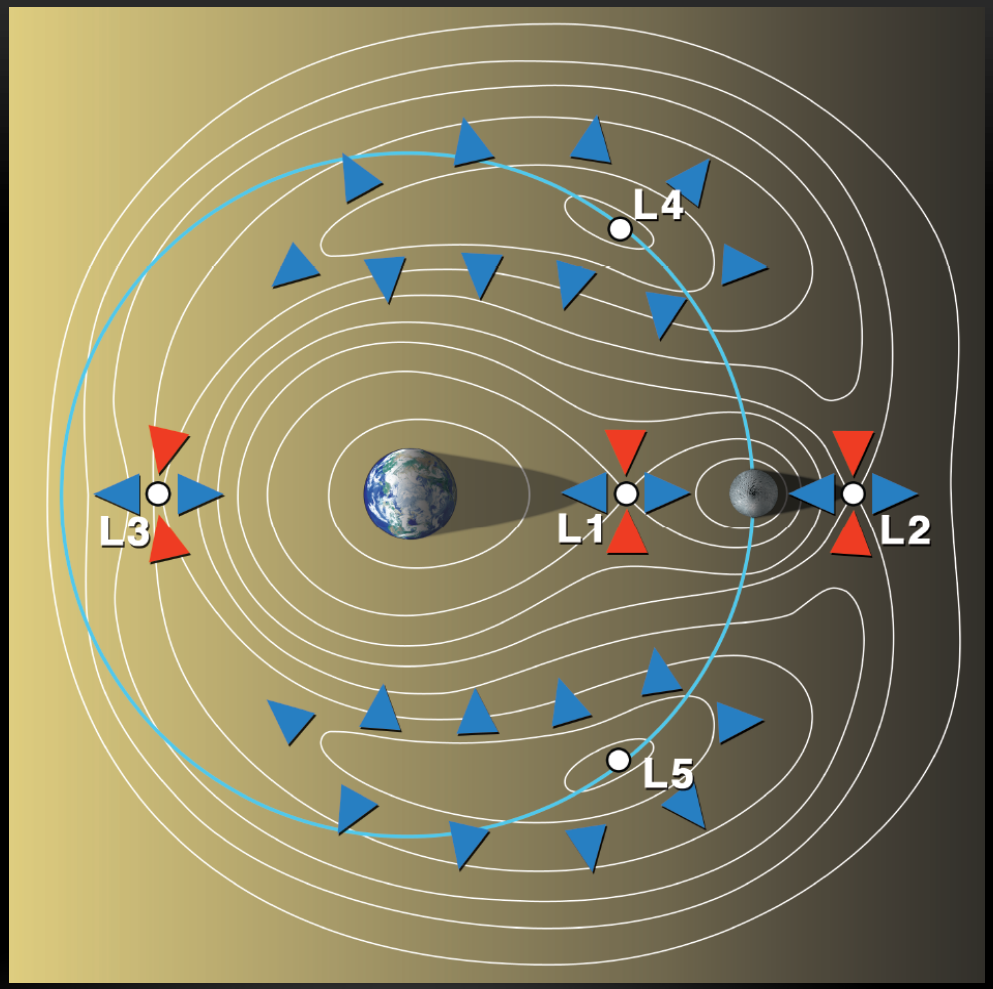
MISSION CONCEPT: ORION MPCV AT EARTH-MOON L2, TELEOPERATE ROVER ON FARSIDE

- L2-Farside mission is much less expensive than Apollo-style missions since no humans would on the lunar surface.
- Mission is affordable with NASA's current & notional outyear budgets.
- Timetable for first mission(s) is late in this decade.



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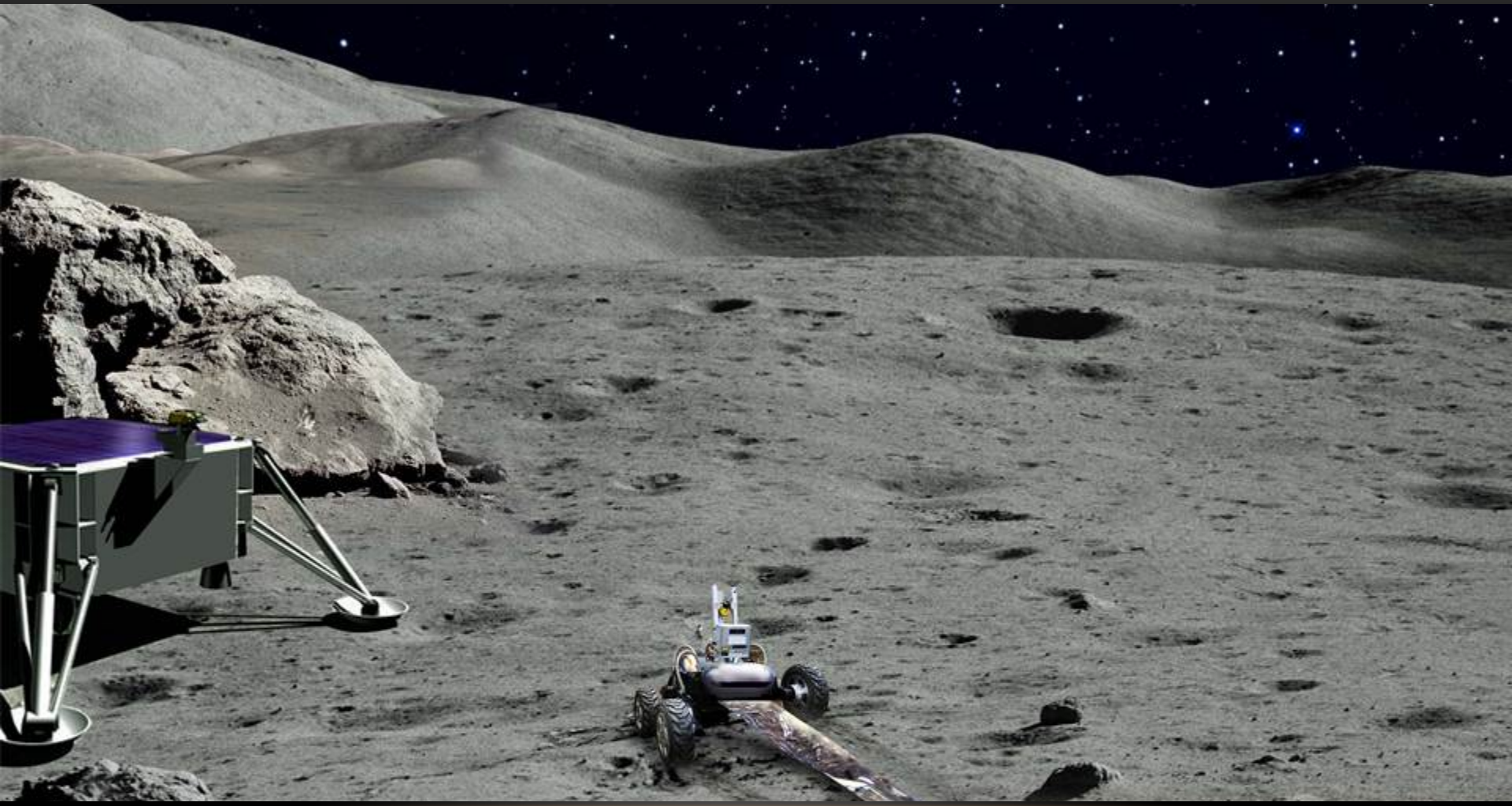
MISSION CONCEPT: ORION PRECEDED BY UNMANNED LANDER + ROVER TO FARSIDE SURFACE



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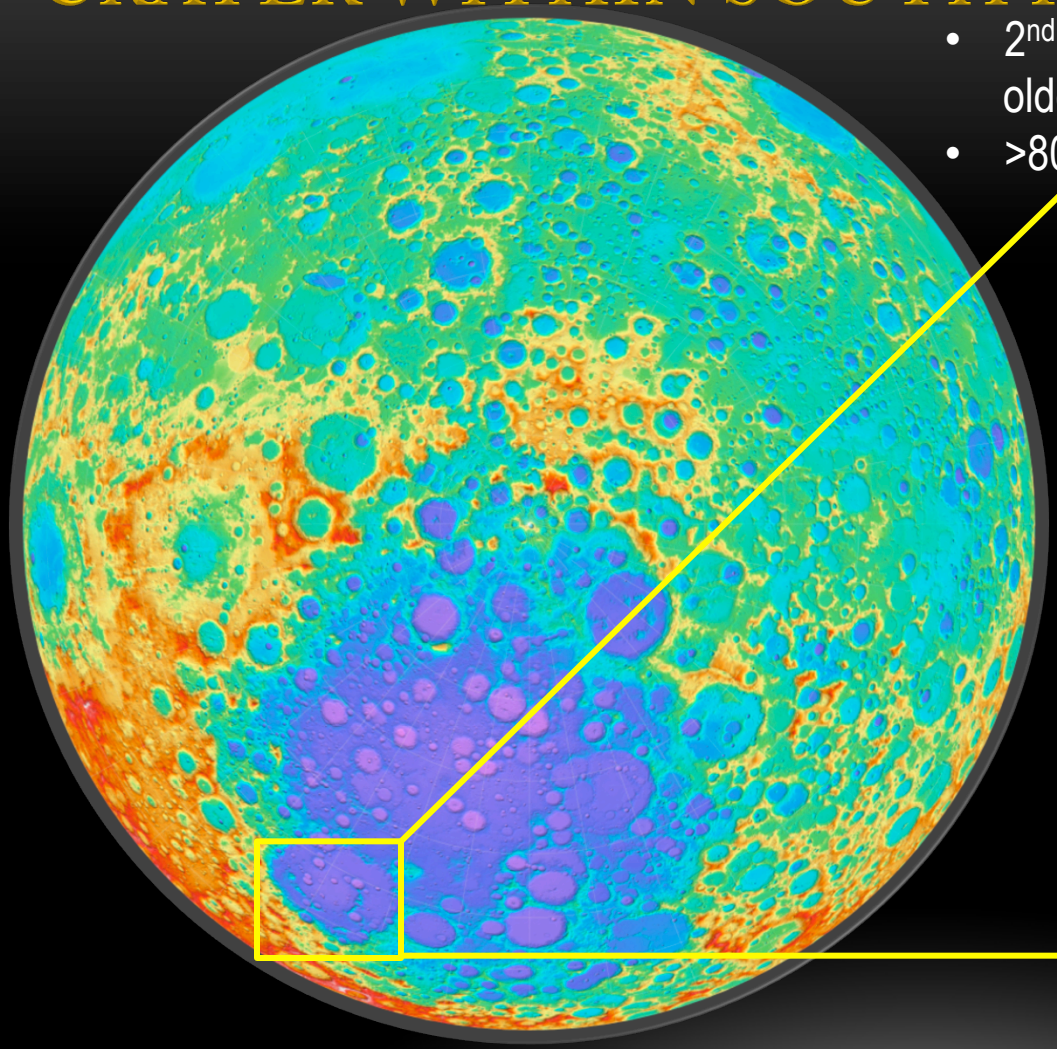
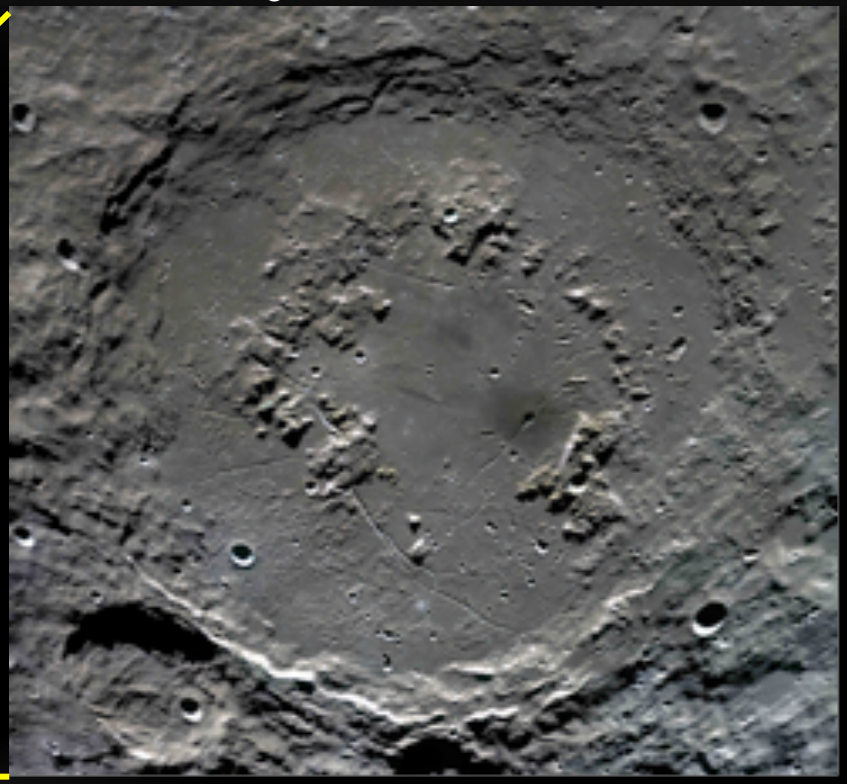
CANDIDATE LANDING SITE: SCHRÖDINGER CRATER WITHIN SOUTH POLE-AITKEN BASIN

- 2nd youngest impact crater (~3.8 billion yrs) within oldest impact basin (~4.3 billion yrs) on Moon.
- >80 dB of shielding from Earth's RFI at 30 MHz.





320 km

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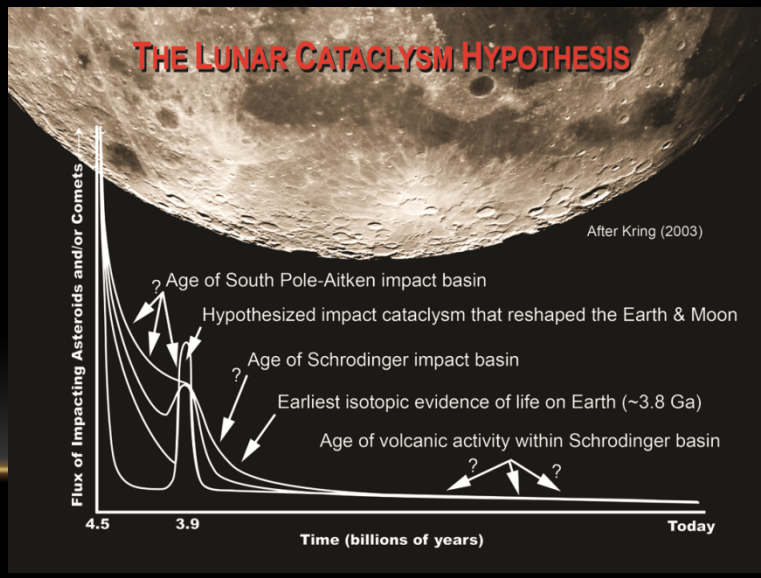
TELEROBOTIC GEOLOGICAL INVESTIGATION OF THE LUNAR FARSIDE

Science Goals

- *Highest priority*: test the lunar cataclysm hypothesis. Earth & Moon severely modified by swarm of asteroids 3.9-4.0 billion yrs ago. => A top science goal of 2011 NRC Planetary Sciences Decadal Survey & NRC report on *Scientific Context for Exploration of the Moon.*
- Determine age of oldest impact basin-forming event on Moon to anchor beginning of basin-forming epoch.
- Provide data on flux of impactors which may have been caused by major rearrangements of giant planets.
- Constraints on delivery of biogenic materials & environmental consequences of bombardment which may be linked to origin & evolution of life on Earth.



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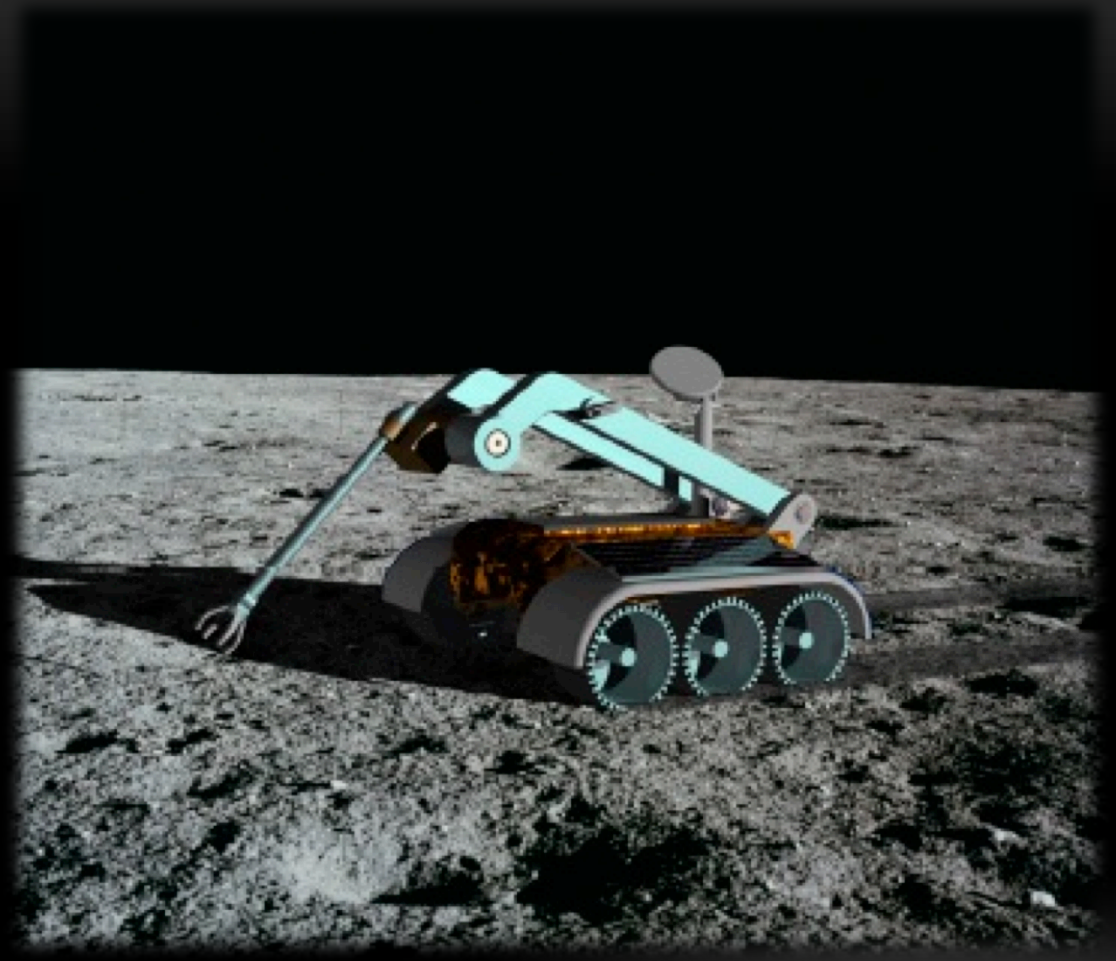
LUNAR SURFACE OPERATIONS



- Produce high quality science while testing operational ideas for future exploration on Moon, asteroids, Mars.
- Crew on Orion implement traverse sequence using telerobotic commands.
- Collect samples for return to Earth & document geologic context.
- Rover instrumentation is minimized but includes high resolution camera, mechanical arm.
- Rover returns samples to lander & ascent vehicle.

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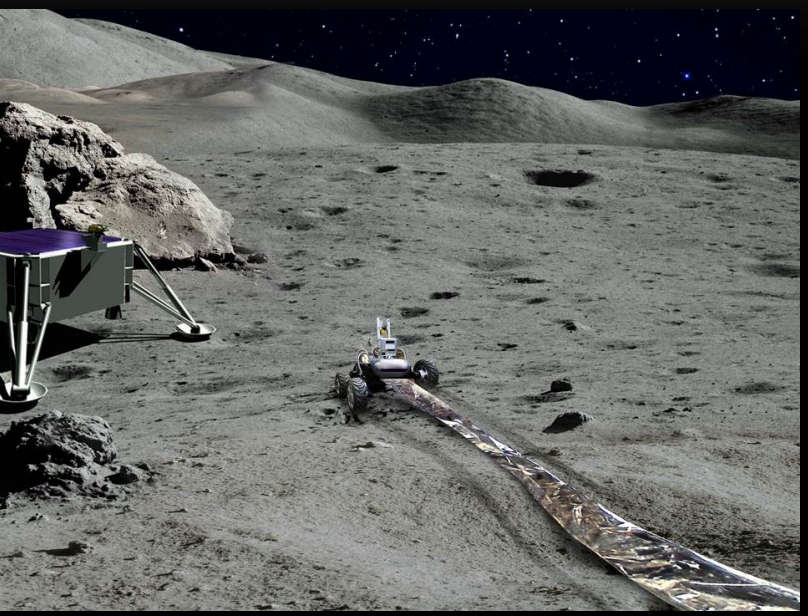
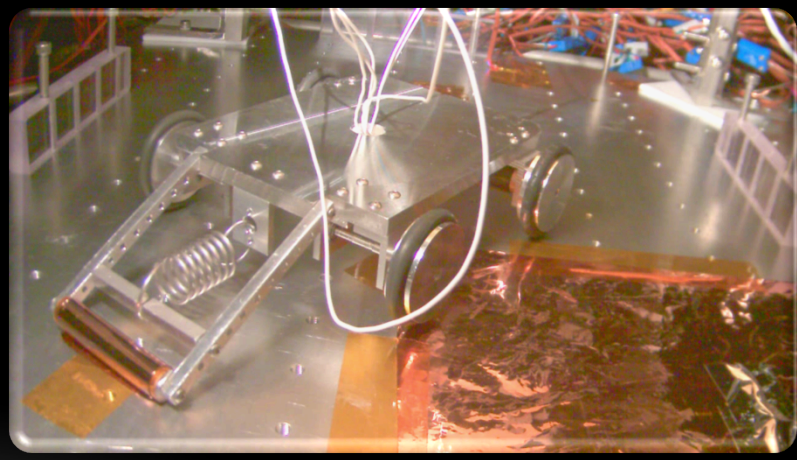
DEPLOYMENT OF POLYIMIDE FILM ANTENNAS

- Metallic conductor deposited on surface of polyimide film.
- Unrolled, deployed by rover teleoperated from Orion on radio-quiet farside.
- Operate at $\nu < 100$ MHz.
- Film tested in vacuum chamber, with thermal cycling & UV exposure similar to lunar surface conditions, & in the field.



Artist's conception of roll-out polyimide film antenna on the Moon

Polyimide antenna test in New Mexico



Rolling out polyimide film inside vacuum chamber with teleoperated mini-rover

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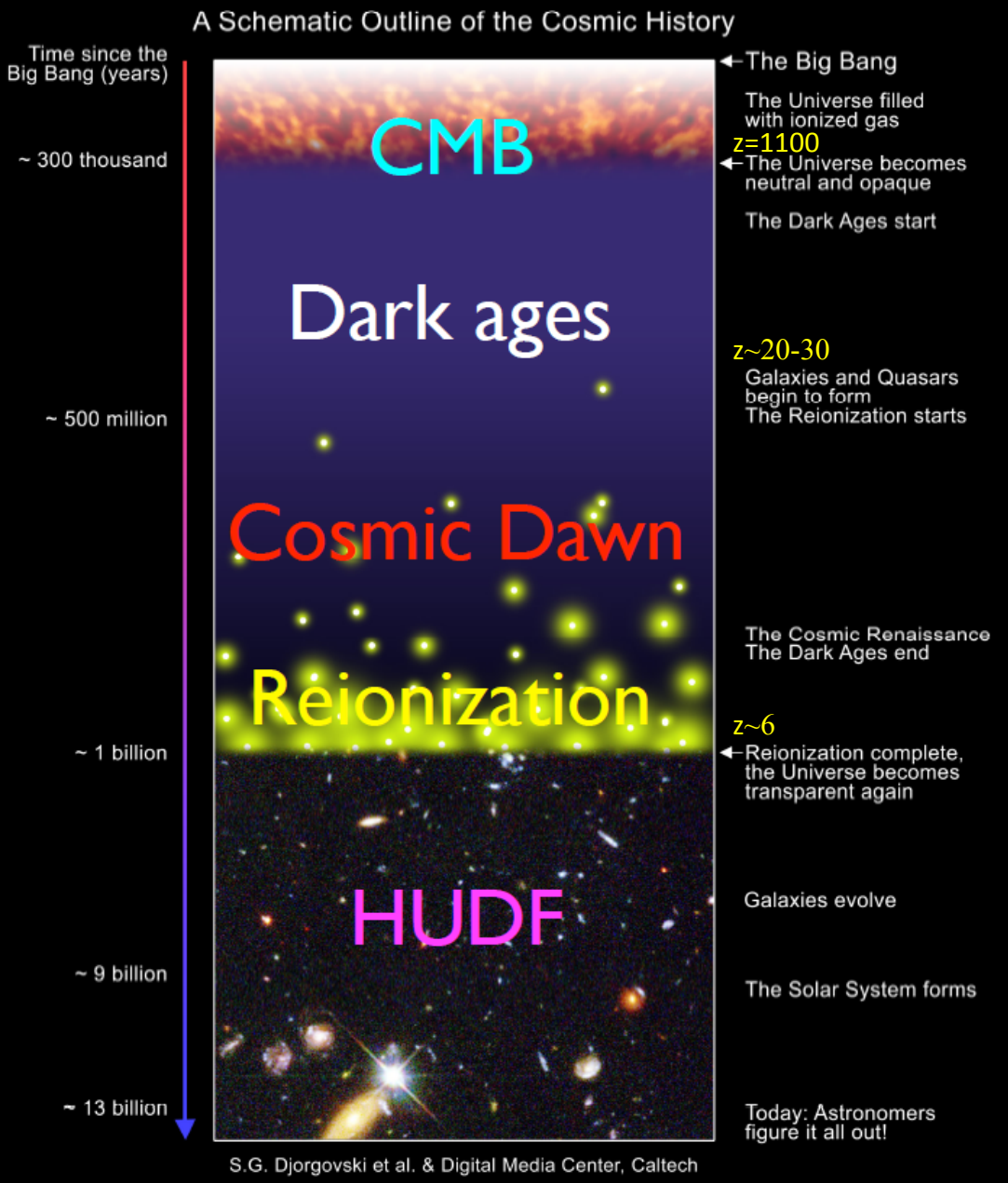
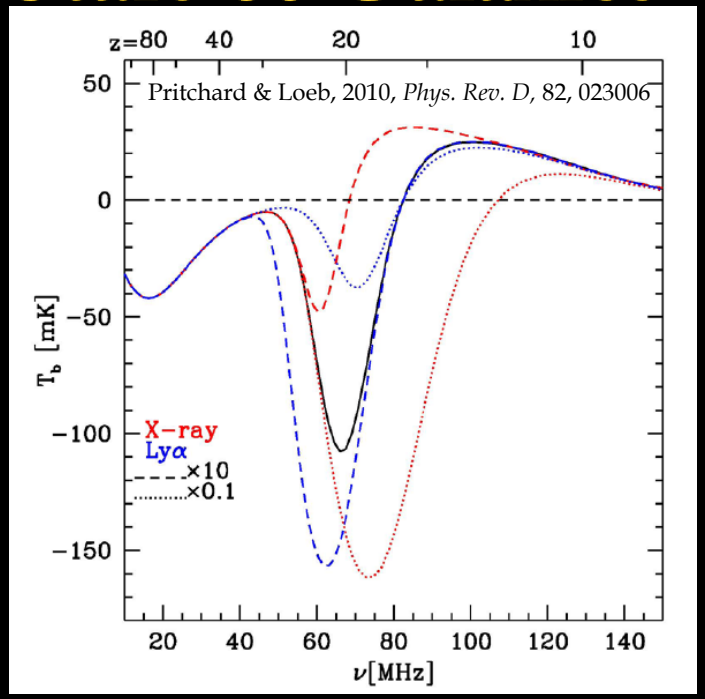
Cosmic Dawn: The First Stars & Galaxies

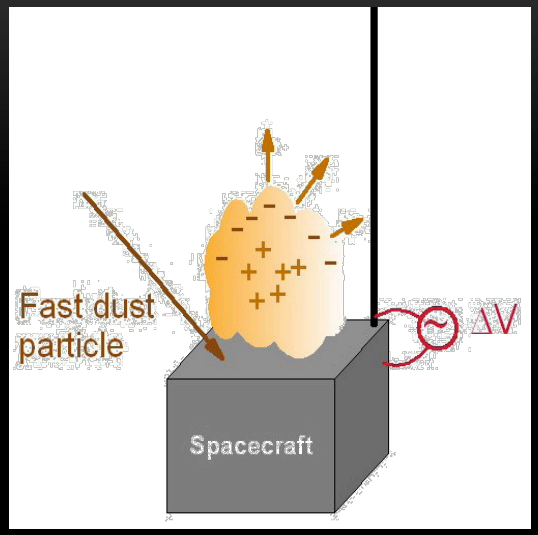




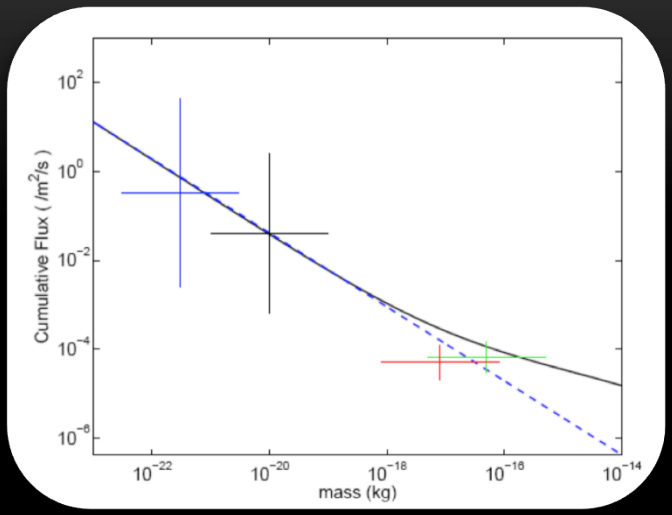
- Hyperfine transition of redshifted neutral hydrogen is only probe of this early epoch.
- Frequencies 40-120 MHz => need lunar farside to be free of RFI and ionospheric effects.
- "Turning Points" in above spectrum measure (1) ignition of first stars, (2) emission from first black holes, (3) beginning of reionization.
- Cosmic Dawn is one of 3 top science objectives for the Astrophysics Decadal Survey: *"What were the first objects to light up the Universe & when did they do it?"*

MEASUREMENT OF INTERPLANETARY NANODUST

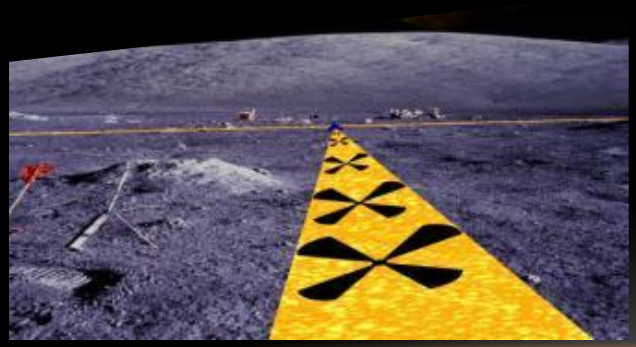
- Nanodust, moving at 100's km/s, may be key source of weathering on airless bodies.



Impact of nanodust grain triggers plasma cloud of electrons that register on radio antenna/receiver.



Flux measured by radio antenna is directly related to mass of dust grains (Zaslavsky et al. 2012, J. Geophysical Research, 117, A05102).



=> For a lunar radio array with three arms of 500 m length, width on the arms of 1 m, total surface area is 1500 m^2 which would yield ~1500 impacts/s for nanodust.

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Measuring the Lunar Ionosphere

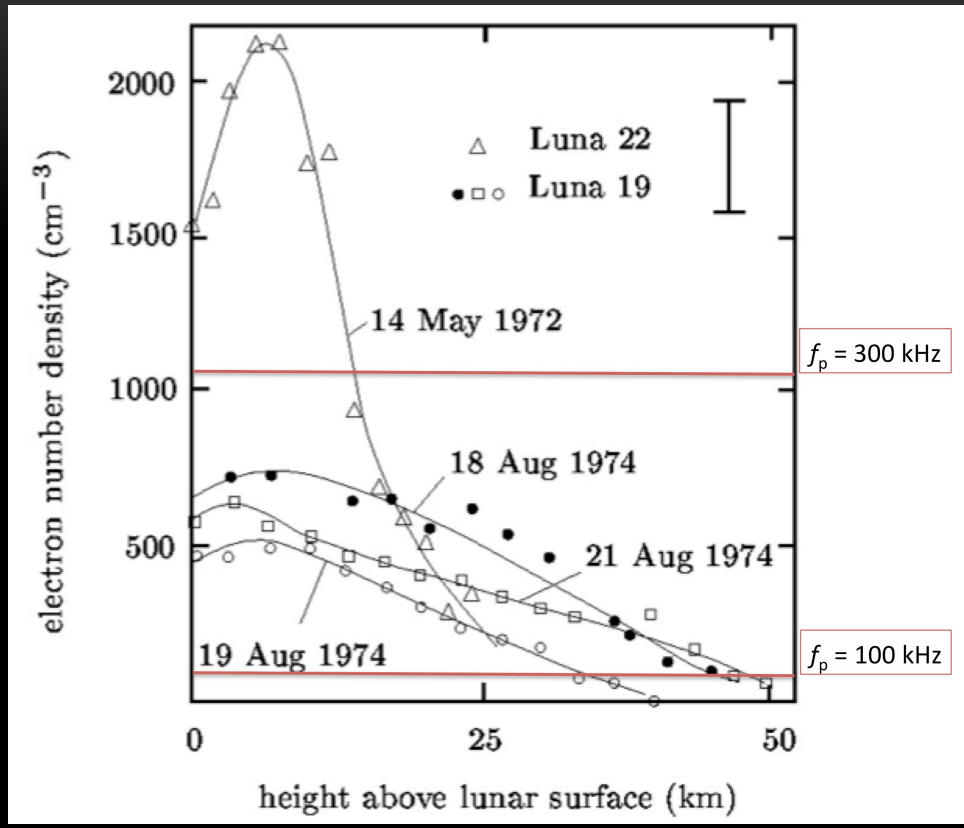
"Planetary exospheres [on] the Moon, Mercury, asteroids, and some of the satellites of the giant planets, are poorly understood …. Insight into how they form, evolve, and interact with the space environment would greatly benefit from comparisons … on a diversity of bodies."

Visions and Voyages for Planetary Science

- Provide lunar surface based method for tracking density of lunar exosphere.
- Electromagnetic waves below plasma frequency cannot propagate:

$$f_p = 9 \text{ kHz } \sqrt{n_e}$$

- Existing measurements suggest highly variable exosphere, both in density and altitude
  - 10^3 to 10^4 cm^{-3}
  - Up 10 km
- Spacecraft based measurements subject to (well-known) systematic errors



Lunar exosphere densities derived from radio occultation measurements with the Luna 19 and Luna 22 spacecraft (Vyshlov 1976; Vyshlov & Savich 1978). Horizontal lines show implied plasma frequencies.

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TELEROBOTICS TEST FROM THE ISS

Collaborators: T. Fong & M. Bualat, NASA Ames
Student: L. Kruger, University of Colorado

- Demonstration of telerobotic deployment of polyimide film is scheduled using Ames K-10 rover and astronauts aboard ISS – Summer 2013.
- Will use Ames K-10 rover on the Ames Mars-scape.
- Mission Operations plan is under development such that ISS crew will teleoperate the K-10 rover, unroll polyimide film, and test for flaws.

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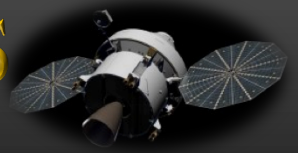
SUMMARY AND CONCLUSIONS



- The proposed L2-Farside mission would be first to investigate surface of the farside of the Moon.
- It would be first to return samples from oldest impact basin in solar system, possibly holding the key to understanding formation & evolution of the Earth-Moon system. Priority for recent Planetary Sciences Decadal Survey.
- The L2-Farside mission would deploy novel polyimide film low radio frequency array in a proven radio-quiet zone which could be first to observe unexplored epoch of the Universe when first stars and galaxies formed. *Cosmic Dawn* is one of three science objectives from current Astrophysics Decadal Survey.
- This mission would be the first to demonstrate teleoperation of rovers by astronauts in orbit from a Lagrange Point.
  - A first demonstration of exploration strategies that will be needed for early missions to asteroids and to Mars.
  - The L2 Lagrange point fits within the "cognitive horizon" for the most efficient teleoperation of a rover (Lester & Thronson, 2011, Space Policy, 27, 89).

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